METHOD TO IMPROVE VIA OR CONTACT HOLE PROFILE USING AN IN-SITU POLYMER DEPOSITION AND STRIP PROCEDURE

BACKGROUND OF THE INVENTION

(1) Field of the Invention

The present invention relates to methods used to fabricate semiconductor devices, and more specifically to a method used to improve the profile of a contact or via hole defined in an insulator layer.

(2) Description of Prior Art

Micro-miniaturization, or the ability to fabricate semiconductor devices with sub-micron features, has allowed the performance of semiconductor devices to be increased while the processing costs for semiconductor chips comprised with devices formed with these same sub-micron features have been reduced. Smaller device features have resulted in a reduction of performance degrading, parasitic junction capacitances. In addition the use of sub-micron features allow a larger number of smaller semiconductor chips to be obtained from a specific size starting semiconductor substrate thus reducing the processing costs for a specific semiconductor chip. The smaller semiconductor chips comprised with sub-micron features still supply device densities equal to, or greater than, counterpart semiconductor chips comprised with larger device

features.

The use of sub-micron features can however present difficulties in specific areas of the semiconductor device fabrication procedure. For example the definition of contact holes used to expose an active device region, or the definition of a via hole used to expose an underlying metal structure, can be difficult to achieve for sub-micron diameter openings, (contact/via holes). The desired narrow diameter opening demands a near vertical profile to allow a maximum of underlying contact area to be exposed, in contrast to a contact hole with a tapered profile in which area of the exposed underlying conductive region has been reduced as a result of the unwanted tapered profile. The reduction in exposed area will deleteriously influence the contact or interface resistance generated at the interface of a metal structure in the contact/via opening and the underlying conductive region. In addition, to terminate the contact/via opening dry etch procedure, an etch chemistry selectively terminating at the underlying conductive region has to be employed, usually resulting in formation of polymer layer, which in turn deleteriously influences the ability to define a sub-micron diameter, vertical profile, for the contact/via opening.

This invention will describe a procedure in which a novel, in situ polymer deposition, and polymer removal cycle, is performed after definition of the contact/via opening in an insulator layer, with this novel, in situ deposition and removal procedure, modifying a tapered profile shape to a more vertical profile shape. Prior art such as Sorlis in U.S. Pat. No. 5,851,302, as well as Yeh in U.S. Pat. No. 6,130,166, describe methods of removing polymer and photoresist after

definition of specific openings, however these prior arts do not describe the novel procedure described in the present invention in which a tapered profile shape of a contact/via opening is modified to a more vertical profile, via a post-definition, intentional deposition of additional polymer followed by an in situ removal step.

SUMMARY OF THE INVENTION

It is an object of this invention to define a narrow diameter contact, or via opening, in an insulator layer, to expose a portion of the top surface of an underlying active device region, or of an underlying metal structure.

It is another object of this invention, after definition of the narrow diameter contact/via opening, comprised with an initial profile shape, perform a polymer deposition and removal procedure, to modify the initial profile shape to a final, and more vertical profile shape.

It is still another object of this invention to remove the additional polymer formed in the polymer deposition step, in situ, in the same chamber used to deposit the additional polymer material.

In accordance with the present invention a method of forming a narrow diameter contact/via opening in an insulator layer, wherein an initial, tapered profile shape is modified to a more vertical profile shape via a post - definition, polymer deposition and removal procedure, is described. A photoresist shape is used as an etch mask to allow a dry etch procedure to define a

narrow diameter opening in an insulator layer, with the dry etch procedure terminating on an underlying, conductive stop layer, which in turn overlays a conductive region such as an active device region, or a metal structure. The dry etch procedure results in formation of polymer material located primarily at the bottom of the contact/via opening, with the defined contact/via opening exhibiting a tapered profile, featuring a smaller diameter opening at the bottom of the contact/via opening when compared to a larger diameter opening located at the top of the opening. With the photoresist shape still in place additional polymer is intentionally deposited, primarily at the bottom of the contact/via opening, followed by in situ removal of all polymer material. The in situ removal of polymer material results in the release of fluorine based radicals from the volatilizing polymer layer, with the fluorine based radicals etching exposed insulator layer surfaces located at, or near the bottom of the tapered contact/via opening, and resulting in a more vertical profile shape for the contact/via opening.

BRIEF DESCRIPTION OF THE DRAWINGS

The object and other advantages of this invention are best described in the preferred embodiments with reference to the attached drawings that include:

Figs. 1 - 5, which schematically, in cross-sectional style, show key process stages used to define a narrow diameter contact/via opening in an insulator layer, featuring an initial tapered profile shape, modified to a more vertical, final profile shape via an in situ polymer deposition and removal procedure.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The method of forming a narrow diameter contact/via opening, in an insulator layer, wherein an initial, tapered profile shape is modified to a more vertical profile shape via a post - definition, polymer deposition and removal procedure, will now be described in detail. Conductive region 1, such as a metal interconnect structure, or an active device region in a semiconductor substrate, for example a heavily doped source/drain region, is provided and schematically shown in Fig. 1. A stop layer, or a material that will exhibit a low etch rate in a etch chemistry used to open a contact or via hole in an insulator layer, is next formed on conductive region 1. Stop layer 2, can be a conductive layer, such as a titanium nitride or titanium disilicide, obtained via plasma vapor deposition procedures at a thickness between about 150 to 400 Angstroms. Stop layer 2, will only be partially removed during the subsequent contact/via opening procedure, therefore remaining to underlay a metal structure to be subsequently formed in the contact/via opening. Therefore for purposes of contact or interface resistance it is imperative that a conductive stop layer be used. Insulator layer 3, such as a silicon oxide layer, or a boro-phosphosilicate (BPSG), layer, is next deposited via low pressure chemical vapor deposition (LPCVD), or plasma enhanced chemical vapor deposition (PECVD), procedures, to a thickness between about 4000 to 15000 Angstroms. A chemical mechanical polishing (CMP), procedure, if desired, can be used for planarization purposes allowing a smooth top surface topography for insulator layer 3, to be achieved. Photoresist shape 4, with opening 5a, is next formed on the smooth top surface topography of insulator layer 3. The

diameter of opening 5a, in photoresist shape 4, is between about 0.20 to 0.25 um. The result of these procedures is schematically shown in Fig. 1.

A dry etch procedure, or a reactive ion etch (RIE), procedure is next used to define contact/via opening 5b, in insulator layer 3, with the RIE procedure selectively terminating at the top surface of stop layer 2. To obtain a high etch rate ratio of insulator layer 3, to stop layer 2, between about 5 to 1, to 20 to 1, a CHF_3 etchant is used, with RIE conditions featuring an RF power between about 500 to 1000 watts, and a pressure between about 30 to 200 mtorr. At the first appearance of stop layer 2, or near the end point of the CHF_3 RIE procedure, polymer layer 6a, at a thickness between about 0 to 500 Angstroms is formed at the bottom of contact/via opening 5b, on the top surface of stop layer 2, in addition to forming on the sides of insulator layer 3, near the bottom of contact/via opening 5b. The formation of polymer layer 6a, comprised of carbon and fluorine, can interfere with the final definition of contact/via opening 5b, not allowing a desired vertical profile to be continued, and resulting in a tapered profile for contact/via opening 5b. The result of the RIE definition procedure is schematically shown in Fig. 2. The consequence of a tapered profile for narrow diameter contact/via opening 5b, is reduced contact area for a subsequent overlying metal structure filling narrow diameter contact/via opening 5b, thus presenting unwanted increases in contact or interface resistance. The diameter at the bottom of contact/via opening 5b, due to the unwanted tapered profile, has been reduced to between about 0.15 to 0.18 um, while the diameter of contact/via opening 5b, at the top of the opening remains between about 0.20 to 0.25 um.

A first embodiment of this invention is to in situ remove polymer layer 6a, in the same chamber used to define contact/via opening 5b. The in situ removal procedure is performed at a pressure between about 500 to 1000 watts, at a pressure between about 30 to 200 mtorr, in an oxygen/argon ambient. This procedure also results in removal of photoresist shape 4. The limited thickness of polymer layer 6a, between about 0 to 500 Angstroms, only resulted in limited levels of fluorine radicals being released from thin polymer layer, therefore resulting in only slight improvements, or modifications of the tapered profile of contact/via opening 5b.

Additional methods of more aggressively modifying the tapered profile of contact/via opening 5b, is next described and schematically illustrated using Figs 3 - 5. A second embodiment of this invention is a procedure to deposit additional polymer, increasing the thickness of polymer layer 6a, located at the bottom of contact/via opening 5b, and resulting in thick polymer layer 6b, with the bulk of polymer layer 6b, again located at the bottom of contact/via opening 5b, and with a thinner portion of polymer layer 6b, formed on the sides of insulator layer 3, exposed in contact/via opening 5b, is next addressed. With photoresist shape 4, in place, deposition of additional polymer layer is accomplished via a plasma procedure performed in situ, in the same chamber used to define contact/via opening 5b, via use of a chamber chemistry containing polymer constituents carbon and fluorine. Thick polymer layer is therefore formed in an ambient using either CH_2F_2, C_4F_8, C_4F_8/CO, C_5F_8, or other carbon - fluorine type gases, at an RF power between about 500 to 1000 watts, and at a pressure between about 30 to 200 mtorr. The thickness of polymer layer 6b, at the bottom of contact/via opening 5b, is between about 50 to

500 Angstroms. The result of the in situ polymer procedure is schematically shown in Fig. 3.

The in situ deposition of polymer layer 6b, is followed by an in situ removal of polymer layer 6b, again performed in the same chamber used for definition of contact/via opening 5b, and deposition of thick polymer layer 6b. The polymer removal procedure is another plasma procedure performed at an RF power between about 500 to 1000 watts, at a pressure between about 30 to 200 mtorr, using an oxygen/argon ambient. The use of the oxygen/argon ambient results in volatilization and dissociation of thick polymer layer 6b, releasing fluorine based radicals 7, from the carbon -fluorine containing, thick polymer layer. A larger concentration of fluorine based radicals 7, is created at the bottom of contact/via opening 5b, than at the top, as a result of the thicker polymer layer residing at the bottom of the opening. This is schematically shown in Fig. 4. While the oxygen component of the ambient results in removal or ashing of photoresist shape 4, as well as of thick polymer layer 6b, the fluorine based radicals attack the now exposed sides of insulator layer 3, specifically at the bottom of contact/via opening 5b, where their concentration was highest, resulting in modification of the tapered profile shape of contact/via opening 5b. The effect of the fluorine based radicals, released during the in situ removal of a thick, in situ deposited polymer layer, is the modification of the tapered profile shape of contact/via opening 5b, achieving contact/via opening 5c, now exhibiting a vertical profile shape, with the diameter at the bottom of the opening equal to the diameter at the top of the opening, between about 0.20 to 0.25 um. In addition to modifying the profile shape of the contact/via opening, the fluorine based radicals also remove a top portion of stop layer 2, exposed